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Strengthening commercial viability through greater inclusiveness in rural mini-grid deployment: Insights from Nigeria and Kenya

Temilade Sesan,[a] Adriana Fajardo,[b] Lucy Baker,[c] Unico Uduka,[d] Mourice Kausya,[e] Daniel Kerr,[f] Elsie Onsongo,[e] Okechukwu Ugwu,[d] Ewah Eleri,[d] Subhes Bhattacharyya[g]

[a] Centre for Petroleum, Energy Economics and Law, 7 Parry Road, University of Ibadan, Nigeria

[b] Independent Researcher, Washington, DC, United States

[c] Geography and Environmental Studies, The Open University, Walton Hall, Milton Keynes MK7 6AA, United Kingdom, and Trilateral Research Chair in Transformative Innovation and Sustainable Development, University of Johannesburg, South Africa

[d] International Centre for Energy, Environment and Development, Bassan Plaza, Central Business District, Abuja, Nigeria

[e] Nuvoni Centre for Innovation Research, Centenary House, Ring Road, Westlands Lane, Nairobi, Kenya

[f] Institute of Energy and Sustainable Development, Faculty of Computing, Engineering and Media, De Montfort University, Leicester LE1 9BH, United Kingdom

[g] Research and Innovation Institute of Sustainable Futures, Faculty of Computing, Engineering and Media, De Montfort University, Leicester LE1 9BH, United Kingdom

Abstract

Amidst the prevalence of energy poverty in sub-Saharan Africa, mini grids have emerged in recent years as a promising solution, not only to bridge lingering electricity access gaps, but also to revitalise rural economies. The realisation of this promise however depends on the extent to which business models, i.e., the value that mini-grid companies offer to different customer segments, are able to respond to the peculiar needs of the largely low-income, agrarian contexts in which they operate. Private developers across the region have been especially innovative in evolving mini-grid business models over time; nonetheless, achieving the goal of commercial viability while serving the majority of rural dwellers remains elusive. Our paper analyses how two private mini-grid developers in Nigeria and Kenya have approached this challenge, introducing business models that address the needs of small-scale farmers for growth while targeting increased revenue for their respective companies. These cases provide evidence for the added value of employing a "Key Starter" model – one in which developers begin to facilitate inputs early on in agricultural value chains, in addition to the latter-stage investments emphasised in conventional approaches to powering the agriculture-energy nexus. Our analysis is grounded in the premise that broad-based development should be pursued in tandem with electricity access provision in low-income agrarian communities across Africa. We conclude that significant financial and policy support, as well as further research and iteration, will be required to realise the potential of the KeyStarter model to resolve the twin challenges of mini-grid viability and inclusiveness at scale.

Keywords: Agriculture-energy nexus; Business models; Commercial viability; Mini grids; Rural development; sub-Saharan Africa.

1. Introduction: Mini grids for energy access and rural development in Africa

Recent estimates indicate that more than 600 million people in Africa – around 43 percent of the continent's population – did not have access to electricity in 2021 (UNDESA, 2023). Most of these people live in sub-Saharan Africa (SSA), where per-capita electricity use is so low it comes to barely 3 percent and just over 1 percent of levels in Europe and the United States respectively (AfDB, 2017; Monyei et al., 2022). The regional average masks significant disparities among countries: the electricity access gap in Nigeria, for example, stands at 40 percent of the country's population, while by comparison, Kenya and Ghana have managed

to bring their access gaps down to 23 percent and 14 percent of their respective populations in recent years (World Bank, 2021).

Beyond a focus on connections, the unreliability of supply limits the utility of electricity even where it is available. Ghana, for example, notwithstanding the relatively high connection rate it has achieved, continues to lose corporate revenue to power cuts; and South Africa's economy has recently been challenged by power generation shortages that have led to regular load shedding (planned outages) (Baker & Burton, 2024). Affordability is another major concern: the International Energy Agency estimates that more than 75 percent of those with electricity connections in the region were unable to pay their bills in 2021 (IEA, 2023). Further, the preponderance of electricity connections is in the urban areas of many countries, leaving rural areas with the most glaring access gaps (Cyril et al., 2024).

The toll on economic and human development in the region is considerable. Lack of access to electricity has been a key factor limiting not only employment and growth rates, but also improvements in critical sectors like education and health (AfDB, 2017). Within this context, mini grids – decentralised electricity generation and distribution systems – have emerged in the last decade as a promising solution to the energy access problem, especially in rural areas (Azimoh et al., 2016; Mambwe et al., 2022; Soares et al., 2023). Indeed, public and private investments in mini grids have ramped up across the region within a short time, although much more – about US$ 127 billion – is needed to realise the global goal of connecting 490 million people to over 200,000 mini grids by 2030 (ESMAP, 2022).

Of particular relevance to the discourse are so-called third-generation mini grids,[1] actively promoted by multilateral actors as being especially capable of surmounting a range of technological and economic limitations in rural SSA contexts – for example, by using "smart" technologies to remotely monitor operations and improve revenue collection (ESMAP, 2019). Notwithstanding high national and global ambitions, however, progress on mini-grid deployment and uptake in the region has been slow. Crucially, the problem of affordability seen with grid electricity customers has surfaced as a significant deterrent in the case of mini grids as well. From Burkina Faso and Uganda to Zambia and South Africa, studies have shown how it remains extremely challenging to operate mini grids in rural areas, where household incomes are typically much lower than the cost of supplying electricity to them (Bensch et al., 2018; Brent & Rogers, 2010; Eder et al., 2015; Kapole et al., 2023).

Low incomes are a feature of rural SSA contexts, where the majority – nearly 70 percent – depend on agriculture for their livelihoods (Uyanga et al., 2024). It is difficult to overstate the importance of agriculture to these economies: collectively, they contribute between 35 and 40 percent of the region's gross domestic product (ibid.; Adediran et al., 2024). Notwithstanding the magnitude of their collective impact, individual farmers mostly operate on a small scale, eking a meagre living out of the land which is often further eroded by the vagaries of nature (Soni & Kawahara, 2020), the volatility of fuel prices (Aye & Odhiambo, 2021) and the market for agricultural commodities (Johnson & Schuh, 2019).

Mini-grid proponents recognise that the dire state of agriculture in the region also presents an opportunity, and there is growing commitment from governments, donors and

[1] A typical third-generation mini-grid system comprises solar photovoltaic panels connected to an inverter (for energy conversion), batteries (for energy storage), and a charge controller (for battery protection). The addition of a diesel generator to a solar mini grid, to provide backup during downtimes, makes it a hybrid system (ESMAP, 2019).

practitioners to power the agriculture-energy nexus with electricity from mini grids (Pueyo & DeMartino, 2018). This touches on what Nuru et al. (2021, p. 1), writing in the Ghanaian context, refer to as the “development co-benefits” of mini-grid interventions: benefits that go beyond electrification to elevate multiple aspects of rural life.

This juxtaposition of precarity and opportunity in rural SSA contexts is what makes the choice of business model especially consequential for mini-grid companies, or “developers” (Ogeya et al., 2021; Vanadzina et al., 2019). Osterwalder et al. (2005, p. 10), in their seminal work aimed at “clarifying” the concept, define a business model as a “description of the value a company offers to one or several segments of customers… to generate profitable and sustainable revenue streams.” It would follow that a worthwhile business model is one that enables profits for a given company while creating optimal value for its customers, an equilibrium that has so far eluded mainstream mini-grid developers in SSA (Ogeya et al., 2021). In other words, achievement of the twin goals of inclusiveness – defined here as maximising value creation for broad segments of rural populations – and commercial viability presents an ongoing challenge for mini-grid practitioners.

In this vein, Dibaba et al. (2023) urge continuous evaluation of existing mini-grid business models to better align them with the needs of rural SSA contexts. Our paper contributes to this effort by interrogating the status quo and providing evidence for a new way of conceptualising the role of mini grids in rural development. Drawing on case studies from Nigeria and Kenya, we show how mini-grid developers in both contexts have adapted to arrive at business models that are attuned to the needs of small-scale farmers for growth while targeting increased revenue for their respective companies. Our analysis points to the utility of a “KeyStarter” business model in which, by investing in the early stages of agricultural value chains, mini-grid developers increase the potential for linking rural energy interventions to broad-based development outcomes.

The rest of the paper is structured as follows. Section 2 reviews the literature on mini-grid business models in SSA, tracing the progression from simple to more sophisticated conceptions of value addition by mini-grid developers in the context. Section 3 describes the methods we used in collecting data on our selected cases, while section 4 describes in detail the findings that emerged from the process. Section 5 discusses the implications of the findings for mini-grid development in agrarian contexts, emphasising the need to situate the current emphasis on private sector participation within broader discourses in development that recognise the redistributive effect of publicly funded inputs in those contexts. Section 6 concludes with a summary of key insights derived from the study.

2. Literature review: Evolving mini-grid business models in SSA

The literature on mini-grid deployment in sub-Saharan Africa (SSA) has gone from being sparse in the early 2000s to featuring scores of academic and grey publications in recent years (Fajardo et al., 2023). This growth has coincided with increasing interest in the potential for expanding electricity access in the region through mini grids, especially those powered by solar photovoltaic technology (Edsand & Bångens, 2024). Development finance institutions – notably the World Bank and the African Development Bank – as well as bilateral organisations have played a central role in driving the recent wave of investment in mini grids (AfDB, 2023; World Bank, 2023a). Perhaps in keeping with the neoliberal bent of these institutions and the relatively recent neoliberal turn in development more broadly (Carroll & Jarvis, 2015), they have been more forthcoming with funding for mini-grid projects in countries like Kenya, Nigeria and Tanzania that have marshalled strong private-sector participation in the sector (Bukari et al., 2021; Herbert & Phimister, 2019).

The rationale for favouring a private sector-driven mini-grid regime is to maximise efficiencies, this being the latest development in the long-running push to privatise erstwhile state-owned power utilities across SSA and institute broad market and regulatory reforms in the electricity sector (Baker et al., 2022; Sesan et al., 2024). A decade of subscribing to this

orthodoxy has left mini grids across SSA facing multiple challenges with regard to achieving inclusive energy access and commercial viability beyond the first few years of operation (Fajardo et al., 2023). Indeed, commercial viability is widely considered to be the most significant challenge to mini-grid expansion in the region (Bandi et al., 2022; Bhattacharyya, 2014). The paucity of proven successful and scalable business models for mini-grid deployment is acknowledged by even the most enthusiastic proponents of a market-driven regime (AfDB, 2016; ESMAP, 2022).

There are several approaches to defining and categorising mini-grid business models in the literature. For this study, we adopt the framework developed by Fajardo et al. (2023), which identifies four distinct but overlapping categories: ownership and management (public, private, community or hybrid); customer focus (i.e., the value proposition for different segments of local markets); tariff structure (i.e., whether tariffs are cost-reflective or subsidised); and portfolio diversification (i.e., the degree of "bundling" of mini-grid investments and operations by individual companies) (see Gill-Wiehl et al., 2022; Lukuyu et al., 2021; Malhotra et al., 2017; van Hove et al., 2022). These categories are delineated in Figure 1.

Ownership and management are defined according to the source of financing for the acquisition and installation of mini-grid assets and the entity responsible for maintaining those assets in the long run. Viewed in this light, many mini-grid projects in SSA are in fact hybrid in terms of ownership, given that financing in the form of donor grants/loans and government subsidies is often made available to private developers to defray their capital expenditure on installation (Babayomi et al., 2023; Zajicek, 2023). However, notwithstanding these supply-side concessions that effectively enable subsidised tariffs in many rural communities, private developers often find the long-term operation and management of mini grids challenging because baseline purchasing power in those communities is extremely low relative to the tariffs charged (Sesan et al., 2024). Regulation in countries like Nigeria and

Kenya that allows private developers to charge cost-reflective tariffs has mainly succeeded in piquing the interest of investors without solving the problem of affordability for rural customers (Carbon Africa Limited et al., 2016; ESMAP, 2017).

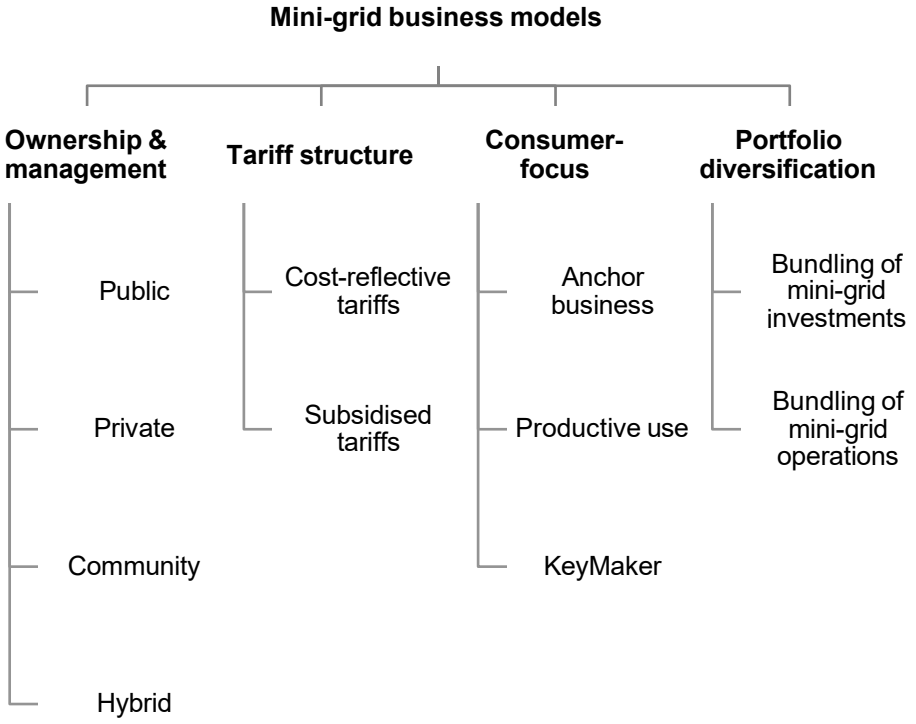

Figure 1. Approaches to categorising mini-grid business models in the literature. Adapted from Fajardo et al. (2023).

The business imperative to enhance the financial bottom line often leads private developers to prioritise communities where they are more likely to recover their costs, a practice that may benefit areas with established demand for electricity but which does little to stimulate new demand from households and smaller businesses (M. B. Pedersen & Nygaard, 2018; Safdar, 2017). Conversely, community-managed mini grids often lack the financial and technical capability for long-term operation and maintenance even where installation has been financed by public or private entities (Bhattacharyya & Palit, 2016; Kumar, 2015).

Public ownership and management models, meanwhile, are widely viewed as lacking the efficiencies enabled by private enterprise, even though they are better suited to socially inclusive outcomes and can mitigate affordability concerns for poor rural communities (AfDB, 2016; Pueyo & DeMartino, 2018). Unsurprisingly, then, donors and development finance institutions often advocate for the use of hybrid models that draw on the comparative advantages of public, private and community actors (ESMAP, 2022). Nonetheless, there remain gaps in the long-term viability of hybrid models, suggesting that there is scope to make them more appropriate to the low-resource contexts in which they are applied.

“Consumer-focus” models are differentiated by the demand for mini-grid electricity by various segments of local markets, including households, micro, small and medium enterprises (MSMEs) and rural industries, or “anchor businesses” (Herbert & Phimister, 2019; Pueyo et al., 2020). Broadly speaking, rural households and MSMEs, despite their ubiquity, have the lowest demand for electricity as well as the least ability to pay for it (Blimpo & Postepska, 2017). Well-established anchor businesses, on the other hand, have much higher levels of demand but are typically too few and far between in rural SSA to be a major income source for mini-grid developers (Fajardo et al., 2023; Falchetta et al., 2022; Hoeck et al., 2022).

In light of these limitations, the strategy of stimulating productive uses has come to the fore in recent years as a way of expanding rural electricity demand beyond niche applications and consequently increasing the commercial viability of mini-grid projects (Farthing et al., 2023; Chattopadhyay et al., 2024; Shrestha et al., 2023; Hove et al., 2022; Terrapon-Pfaff et al., 2018). Accordingly, identifying ways to incentivise productive uses of electricity has become a priority for developers in designing and implementing mini-grid projects (Falchetta et al., 2022). The scope of the task is considerable: in Nigeria, for example, the World Bank recently earmarked US$ 19 million to finance the uptake of productive-use equipment by MSMEs (REA, 2024). Worldwide, the global energy non-profit Power for All estimates that US$ 3 billion will be needed to finance the purchase of end-use equipment by mini-grid

customers in the lead-up to 2030 (Power for All, 2019). Notwithstanding the optimism surrounding the idea, however, the evidence is unclear as to whether increasing productive uses really does boost the commercial viability of mini grids (Fajardo et al., 2023).

One area in which the ability to stimulate productive uses is highly consequential is the agricultural sector, given that it employs the majority of rural SSA dwellers (Davis et al., 2017; Yeboah & Jayne, 2018). Growing recognition of this reality among investors and developers has led to the articulation of an agriculture-energy nexus and the active pursuit of avenues for enhancing agricultural productivity with mini-grid electricity (Falchetta et al., 2022; GEAPP, no date). A major area of focus for nexus initiatives to date has been small-scale agro processing, whereby micro businesses in the value chains of staples such as palm oil, rice and cassava are targeted with electrical equipment for processing harvested crops (ibid.). Notably, this market segment is distinct from the larger agro-processing industries that are target customers for both grid and mini-grid operators under the anchor business model (Herbert & Phimister, 2019).

Other initiatives implemented under conventional framings of the nexus support energy inputs at different points along agricultural value chains, including solar-powered irrigation to improve yields and cold storage to extend the life of perishable crops (Nadji.Bi Sénégal, no date; REA, n.d.; Schmitter et al., 2018). While mini-grid developers have been innovative in deploying these initiatives, they have not been sufficient to drive significant increases in electricity demand in agriculture-dependent economies (Ngowi et al., 2019). This shortcoming has paved the way for the KeyMaker model, where mini-grid developers go a step further to spur local demand by participating directly in agricultural value chains, usually at the later stages of processing, marketing and transportation (Cabanero et al., 2020; Pueyo et al., 2022). With this model, developers essentially diversify their portfolios beyond electricity generation and distribution to other sectors of the rural economy, on the premise

that their long-term prospects will be enhanced if they help build the capacity of local value chains to absorb energy inputs.

The KeyMaker model also expands on the bundling approach to portfolio diversification in which a developer combines multiple projects into fewer assets in a bid to increase economies of scale and mitigate investment risk in what is widely acknowledged to be a high-risk sector (Chamarande et al., 2024; Wagemann & Manetsgruber, 2016). Bundling may be practised within dedicated investment portfolios in specific geographical clusters, or it may apply more broadly across a developer's operations. In contrast to the KeyMaker model, the assets and investments involved in bundling are typically mini-grid or energy-related, but they may vary by location (i.e., rural or urban), delivery model (Engineering, Procurement and Construction (EPC) or Energy-as-a-Service (EaaS)), or sector (agriculture, commercial and industrial, health, etc.) (Fajardo et al., 2023; Huber et al., 2021).

It is apparent from the foregoing that the evolution of business models for mini-grid deployment in SSA has been characterised by increasing novelty and resourcefulness on the part of investors and developers alike. The KeyMaker model is of particular interest for its potential to enhance the utility of productive-use approaches at the agriculture-energy nexus. Nonetheless, questions remain as to how far the model can go in simultaneously enabling rural productivity and developer profitability in different rural SSA contexts, and how it might be improved upon in practice.

Following the identification by Ngowi et al. (2019) of the need for more descriptive case studies that can facilitate our collective understanding of the pathways to rural transformation enabled by electrification, our paper examines in depth the respective business models adopted by two private mini-grid companies in Nigeria and Kenya. The cases are instructive for the insight they provide into the opportunities and challenges presented by the adoption of consumer-focus models in traditionally low-yield rural value chains, and the possibilities

presented by reaching backward (as well as forward) into those value chains under what we term a “KeyStarter” model. First, however, we describe the methods we employed in gathering data for the analysis in both countries.

3. Methodology

In seeking to understand the respective motivations and operations of our case study companies, we utilised a qualitative research approach for primary data collection. Qualitative methods facilitate open-ended yet in-depth exploration of topics of interest in a manner that centres the perspectives of research participants (DeJonckheere & Vaughn, 2019; Ritter et al., 2023) with the aim of gaining nuanced insight into inherently complex human and social phenomena (Ahmed, 2024).

The participants in our study were the owner-managers of twelve mini-grid companies, – five in Nigeria and seven in Kenya. This group is a subset of a wider range of participants we engaged with in a larger study comprising four sub-Saharan African countries (the other two being Tanzania and Senegal) from February to May 2022, which elicited perspectives on the development and impacts of mini grids from public, private and community-level stakeholders. The experiences of Company A and Company B, described and analysed below, emerged from our fieldwork in Nigeria and Kenya as the ones with the most relevant insights for the present analysis. The other ten companies largely followed conventional productive-use approaches and were therefore less suited to the paper’s objective of learning from more novel attempts at inclusive mini-grid deployment.

The main technique used in our fieldwork was semi-structured interviewing, which in its most faithful iteration can approach an art form given its sensitivity to emotional as well as intellectual cues (Adams, 2010). We deployed an identical set of interview guides in both countries, which enabled a degree of standardisation across our cases but also allowed for adaptation to the requirements of individual interactions in each context (Kallio et al., 2016).

The interview guide explored questions relating to the opportunities and risks for investors in the mini-grid sector; avenues for mini-grid project financing; the dynamics of uptake of mini-grid electricity in project communities; and the prospects for cost recovery and long-term viability in the challenging rural contexts in which mini-grid companies operate. The overarching aim of the line of questioning in the guide was to interrogate contemporary narratives regarding the ability of existing mini-grid business models to simultaneously deliver profits to private developers and boost productivity for rural dwellers (see Wassie & Ahlgren, 2024).

All twelve developer interviews conducted in both case study countries were fully transcribed on account of their importance, considering that they were given by "key" informants who are traditionally regarded as knowledgeable experts in a given domain (Taylor & Blake, 2015). This was followed by an in-depth review of all the interview transcripts, to build familiarity with the entire subset of data. The transcripts were subsequently coded, first deductively, according to a set of predetermined themes identified in the literature, and then inductively, following insights emerging from the data itself (see Chandra & Shang, 2019; Fereday & Muir-Cochrane, 2006). This two-way coding process (outlined in table 1) generated a fine-grained analysis that enabled the identification of key differentiating features common to our two case-study companies. The next section describes the cases in detail.

Table 1. Codes generated from analysis of qualitative data

Themes (corresponding to mini-grid business model categorisation)	**Sub-themes**	**Related codes**
Ownership and management	Public ownership	Political context; Government contracting; Tension with DisCos; Constituency projects.

	Private ownership	Social enterprise model; Market development; Returns on investment; Financing; Investment risks and mitigation strategies; Business size and strength; Technical skills and entrepreneurial capacity.
	Hybrid ownership	Collaboration with public, private, and community entities; Integration with public and private sector support; Financing models.
Tariff structure	Cost-reflective tariff	Adjustment for agricultural productivity gains; Revenue generation; Economies of scale; Tariff setting; Commercial viability; Collections and cost recovery; Global trade and supply chain issues.
	Subsidised tariff	Early-stage financial support for farmers; Performance-based grants; Internal cross-subsidisation; Demand-side subsidies; Affordability; Energy justice.
Consumer focus	Productive use	Low agricultural productivity; Enhancing agro-processing; Solar-powered irrigation; Cold storage solutions; Agriculture-energy nexus.
	KeyMaker	Direct participation in agricultural value chains; Capacity building in agriculture; Infrastructure development; Investments in processing and marketing; Investments in transportation infrastructure; Technical assistance; Agriculture-energy nexus.
	KeyStarter	Investments in early-stage agricultural value chains; Broad-based rural development initiatives; Iteration and testing; Local knowledge; Access to credit; Demand-side stimulation; Agriculture-energy nexus.

Portfolio diversification	Bundling of mini-grid investments	Mixed portfolios by geography.
	Bundling of mini-grid operations	Mixed portfolios by technology; Mixed portfolios by delivery model; Mixed portfolios by sector; Mixed portfolios by service.

4. Case studies

4.1 "How can we help?" Private-developer experiences growing smallholder-farmer yields in Nigeria

Company A is a home-grown enterprise located in Abuja, the Nigerian capital, with operations in several regions of the country. The company describes itself as a "mainstream energy-access company," which is a much broader characterisation than the more common, narrower designation of mini-grid developer. The company started out installing standalone solar power systems for commercial and industrial (C&I) clients in urban areas of the country with high electricity demand but low supply from the grid. It subsequently integrated public-sector clients, mainly state-owned health centres in both urban and rural areas, into its portfolio.

For its C&I and public-sector projects, the company employs both the EPC and EaaS delivery models. Under the EPC model, the company builds solar systems on demand and then hands over maintenance of the infrastructure to the client. With the EaaS model, the company makes the required upfront investment in infrastructure and the client only pays for the electricity supplied over time. The prerogative in all cases is to reduce the cost of private electricity generation for the company's clients, many of whom have historically relied heavily on diesel – the price of which has risen geometrically in recent years in keeping with global oil price hikes (Osae-Brown, 2022).

Against this background, rural mini grids are a relatively recent addition to the company's portfolio of energy-access projects, the first plant having come online in response to an open call for proposals in 2017, seven years after the company began operations. As will become apparent, the company's versatility and flexibility in continuously expanding and diversifying its portfolio is a feature that is central to its ability to reimagine the agriculture-energy nexus and redefine its own role within that nexus. Perhaps most instructively from a business perspective, the company has retained the profitability imperative notwithstanding its commitment to catalysing development in areas that are traditionally viewed as being commercially unviable.

Nonetheless, the foray into rural mini grids presented a new kind of challenge for the company. Although it deploys an EaaS model similar to the one it uses with institutional clients in the public and private sectors, the returns on its investments in rural mini grids are not as guaranteed given that the the majority of prospective subscribers to the latter are smallholder farmers whose incomes are low and irregular (FAO, 2022; Ikuemonisan & Ajibefun, 2021). Consequently, the company has experienced a steep learning curve with this customer segment, one characterised by successive rounds of testing and iteration, retrospectively applying lessons learned from early failures. Crucially, the company's experience demonstrates the potential advantage that local mini-grid developers have in being able to harness their affinity with rural energy users to emerge with contextually appropriate business models.

4.1.1 Learning from early failures: testing and iteration

> "So, we said, let us take a pause. This whole noise about productive use of energy is something that has to stop. What are the problems…"? – Company A_CEO

As indicated above, the company's first mini-grid project was implemented with a grant received from a donor – the United States African Development Foundation – in 2017, as part of an ongoing series of off-grid energy "challenges" aimed at spurring innovation among private developers in the sector (USADF, n.d.). The timing of the grant coincided with the emergence of third-generation mini-grids in the country, a period in which the emphasis in the sector was more on demonstrating the feasibility of the technology in rural contexts than on ensuring the commercial viability of new installations. Perhaps unsurprisingly, this first mini grid proved unable to pay for itself over time, with the company realising less than a tenth of the projected revenue in the first few months. This early experience demonstrated both the utility of grants for nascent renewable energy markets and the need for private developers to take a more informed approach to laying the foundations for the commercial viability of rural mini grids.

The company responded to this setback by developing and trialling a system for vetting prospective host communities for future mini grids:

> "So, we sat down and we started developing our own theories. We did a lot of research, we prototyped different tariff models… developed those tariff models in the local language with the people across two communities. We were doing a lot and were documenting all our findings. We then developed our own process on how to identify a commercially viable community." – Company A_CEO

Even with this development, however, demand was still limited in ostensibly viable host communities, and it became the accepted wisdom in the mini-grid sector that developers would have to take additional steps to stimulate latent demand in those communities. The company rode this general wave initially, helping would-be rural entrepreneurs launch new avenues for productive uses of mini-grid electricity:

> “We created a barbing salon for a barber, we created a viewing centre for a guy. There is one woman - I will never forget her story - whom we created a provision store for. She had a fridge and freezer; she could send her children to school. All sorts of stuff like that. We then started seeing consumption go up.” – Company A_CEO

While this approach enabled modest gains, as expressed in the quote above, it did little for productive users in the agricultural sector. Following the conventional wisdom at the time, the company began to extend credit lines to agro processors in host communities to help the latter replace their diesel-powered milling machines with electrical ones that would be connected to the mini grid. The electric machines did come onstream, but they ended up being barely operational. The company’s own research unearthed several deterrents to local acceptance of the new machines, including customer complaints about the texture of the finished product (the grain was too finely ground) and the incompatibility of the electricity billing system with the in-kind payment system that was the norm in some host communities. The common challenge that cut across all the communities, however, was that there was simply not enough incoming grain to keep the electric machines running for a substantial length of time:

> “…we now saw that the issue is that… the diesel milling machine doesn’t work for more than maybe one hour in a day, meaning that the produce that is coming out of the community is not sufficient to even keep a mechanical milling machine operational… You help the guy who has a mini-machine to convert to an electrical mini-machine; that doesn’t solve the problem because 80 to 90 percent of the people in most of these rural communities are farmers, and they are subsistence farmers.” – Company A_CEO

This crucial discovery prompted the company to re-evaluate its assumptions regarding the drivers of productive uses of energy in rural areas, and in the agricultural sector in particular, and to alter its business model accordingly.

4.1.2 Building a business model from the bottom up

> "So, we start by saying, 'how can we help?' Because the starting point is to help the farmers increase their output." – Company A_CEO

The key inference that the company drew from its experience with the electric milling machines was that increasing agricultural yields was central to stimulating rural energy demand to a degree that could render mini grids commercially viable in agrarian communities. To test this idea, the company decided to invest in the operations of five smallholder farmers, each cultivating between three and five hectares of land in a typical farming season. The company's intervention was comprehensive, encompassing both technical and financial inputs: they provided the farmers with credit, improved seedlings, farm machinery and extension services – all the while monitoring the farmers' progress and making required adjustments along the way. This initial investment was done internally, using the profits from other business lines – another indication of the merits of portfolio diversification for rural mini-grid operators.

The results of this experiment were remarkable: within one planting cycle (in this case, between June and December), the farmers had tripled their yields, from an average of four to 13 hectares per farmer. The company went a step further: it linked the farmers to another company that bought the harvest wholesale, enabling the former to pay back their loans

promptly, even with the 15-percent interest charged by the company.[2] The outcomes were so positive overall that the company decided to scale up from 13 to 400 hectares in a second round of investment, this time inviting people on its staff to commit personal funds to the project given that the model had been tested and had proven profitable.

Within the limits of this case, therefore, the model seems to have resulted in a win-win scenario for both the company and the local farmers whose operations are expected to drive demand for the electricity generated by new mini grids. This is a potentially ground-breaking prospect, as it can help developers and funders mitigate the risk of reinforcing existing inequities between smallholder farmers and the more established rural enterprises that are often better positioned to benefit from mini grids because their baseline demand for electricity is relatively high (see, for example, Pueyo et al., 2020).

There is still a long way to go in this regard: Company A has the ambition of scaling up its intervention to thousands of hectares across several communities, and it realises that downstream functions such as crop storage and, eventually, processing, will need to be integrated into its model if it is to reap the full benefits of its investments in rural agriculture. Nonetheless, the key innovation by the company lies in its recognition of the value of starting productive-use interventions at the beginning of agricultural value chains, in addition to the later stages of processing and cold storage that have been the main focus of many donors, governments and developers (see, for example, REA, n.d.; USAID, 2022). The company's valorisation of a bottom-up approach to energising productive uses is particularly noteworthy for the way it went against the grain of established incentives for developers at the time:

[2] This is much lower than the interest rates levied by many commercial banks on prospective borrowers in the agricultural sector, especially those, like smallholder farmers, deemed to have poor credit histories. The most recent rates published by the central bank (i.e., for February 2023) are as high as 36 percent for borrowers in this category (Central Bank of Nigeria, n.d.).

> "[Donors] wanted all developers to have milling machines in their mini grids. How are they going to be sustainable? But we just felt that at the end of the day if we are in this business, we understand it better, we are the ones who go to these communities. We should be able to do better…" – Company A_CEO

The above quote underscores the company's dual outlook, highlighted earlier, that has helped it adapt to the realities of rural contexts while keeping the profit motive in view. By putting its money where smallholder farmers at the very bottom of the value chain also have a chance to benefit, it appears to have chosen to deploy the profit motive in the service of development. Remarkably, it has achieved this while operating as a mainstream business, rather than as a rural development entity:

> We've raised more debt than grants. We are still a privately funded company, so we don't have an external investor in our books… The funds we raised last year was almost 2 billion naira[3] and it was 100 percent debt. We will continue to raise debt and use debt in an efficient manner to create these projects… - Company A_CEO

This case is instructive for developers, particularly in the present era in which private-sector actors are expected to play a prominent role in mini-grid deployment in Africa (IEA, 2023; World Bank, 2023b). However, as we argue below, it is perhaps even more so for the governments and development partners responsible for making policies and allocating public resources to rural initiatives. An integrated approach to enabling energy access for rural development is one that needs to be supported by all stakeholders if it is to be scalable and sustainable in the long term.

[3] This is approximately USD 5 million at the January 2021 exchange rate of USD 1 = NGN 383.

4.2 Chicken change: Private-developer experiences supporting small poultry farmers in Kenya

Company B is a private enterprise, founded in 2011, that owned and managed 15 operational mini grids across Western Kenya at the time of our fieldwork in 2022. The scale of company B's operations is substantial for a mini-grid utility, having enabled the connection of 6,060 households, as well as several businesses and institutions, to its distributed electricity networks.

The company, an offshoot of a parent company headquartered in the global North, started out with electricity provision as its core focus. In the years since the company's establishment, Kenyan mini-grid regulation has evolved to allow cost-reflective tariffs, in principle enabling private developers and investors to recover their operating costs. This favourable development notwithstanding, it became apparent that the proceeds from company B's core business would not be sufficient to keep its mini grids commercially viable. Consequently, as was the case with company A in Nigeria, the company expanded its remit to include productive-use initiatives – in particular, the financing of grain-milling equipment – in the hopes of boosting demand for the electricity it was generating in host communities.

Notably, in addition to financing the acquisition of productive-use equipment by micro-businesses, company B also introduced electrical appliances – including pressure cookers, kettles, irons, blenders and television sets – for household use in its host communities. The main financing instrument for these appliances is a pay-as-you-go scheme that requires

households to make a small down payment, which varies by appliance, and then pay the balance (including interest) in monthly instalments until the debt is paid off.[4]

A similar pay-as-you-go system was established for the payment of connection fees: households have the option of making an initial down payment of KES 200 (USD 1.54) for connection and having the balance amortised into their electricity purchase over time. Under this arrangement, a standard 20 percent of every electricity token purchase goes toward repaying the balance on a household's connection fee, while the remainder yields electricity units for the customer.

This model has enabled widespread ownership of electrical appliances in project communities; nonetheless, it creates several challenges that mirror the dynamics of low input levels among productive-use customers and reflect low levels of financial capital at the household level. Many household customers, constrained by a combination of low incomes and high tariffs charged by the utility, end up underutilising the appliances they purchased under the pay-as-you-go scheme. Further, since low-income households tend to buy electricity tokens in small amounts per time (typically less than USD 1.00 daily), there is very little left over for actual electricity consumption once the payment toward the balance of the connection fee is deducted from a purchase.

Attuned to these limitations in the rural economies it serves, company B in 2019 strategically began to integrate contract poultry farming into its business model, organising farmers into groups along the entire poultry value chain. Similar to company A, the company starts

[4] As an example, an electric pressure cooker with a sticker price of KES 6,250 (USD 50.15) is offered at KES 6,840 (USD 52.62) under the pay-as-you-go scheme, i.e., with 9 percent interest. Households make a down payment of KES 1,800 (USD 13.85) to acquire the appliance and pay the balance in monthly instalments of KES 280 (USD 2.15). The maximum repayment period allowed is 18 months.

facilitating access to inputs – incubators, veterinary care, extension services, and processing equipment – to contracted farmers at the early stages of the value chain. Instructively, and in line with the KeyMaker model, the company also facilitates access to external markets for the high-quality eggs and processed chicken that emerge nearer the end of the value chain. The revenue model is such that, upon the sale of the poultry products in the market, company B deducts its operational expenses and a share of the profits realised, and the remainder is distributed among participating farmers.

In 2021, company B decided to reach back even further in the value chain by partnering with another company on an initiative focused on improving the quality of poultry feed used by its contract farmers. This latter initiative involves the use of organic food waste sourced from municipal markets to rear black soldier fly larvae, which are then used as a protein-rich component in the poultry feed sold to the contract farmers. Company B facilitates the collection of the food waste from local markets, again beginning its intervention at the start of the organic poultry-feed value chain. The larvae-rearing company relies on company B's electricity to operate its machinery, and in return, the latter benefits from increased electricity sales. In addition – and importantly for company B's interests in poultry farming – its involvement in the organic feed value chain boosts its prospects for turning out superior products for the market at the end of the value chain.

Again, as with company A above, there are challenges to this process that underscore the need to iterate and improve on the model. The poultry farmers involved run very small operations, and therefore face financial barriers that require substantial inputs to overcome. Further, operational challenges such as quality assurance on the supply side and market fluctuations on the demand side pose risks to the model for both the developer and the farmers, necessitating the adoption of context-responsive management and adaptation strategies.

Overall, however, we see evidence of company B trying to build, almost from scratch, an entire ecosystem that develops the capacity of whole communities to use and pay for the electricity it generates, so that its mini grids can operate on a self-sustaining basis. Beyond its forays into poultry farming and organic feed production, the company has integrated e-mobility services into its business model by introducing mini grid-powered bicycles and tricycles for hire by local motorcycle taxi operators. As of 2022 when this project was in its pilot phase, revenue was generated from daily rental fees of KES 500 (USD 3.85), covering both bicycle/tricycle usage and battery charging, with any additional earnings belonging to the rider. The company provides a dedicated battery swapping station, allowing riders to exchange depleted batteries for fully charged ones. Notably, riders can do multiple swaps in a day at the fixed daily charge KES 500, increasing the model's value proposition to them.

Company B recognises that further research and development are required to make the technology and payment mechanisms more compatible with conditions in the poor rural contexts in which they operate. The crucial point is that the company continues to evolve its model to respond to the needs of broad segments of prospective customers in local value chains, rather than only intervening at selected points where the value added is most immediately apparent. In the next section, we highlight key similarities between the strategies employed by companies A and B in spurring local demand and discuss their implications for the pursuit of agricultural transformation through rural electrification.

5. Discussion: Leveraging a KeyStarter model for inclusive growth in agricultural value chains

The Nigeria and Kenya cases described above exhibit similarities in the way the business models used by the respective mini-grid developers evolved over time, even if the specifics differ. The Nigeria case, in particular, depicts an organic learning curve, one in which the developer went from unquestioning adherence to the assumed logic of productive-use viability to a more reflexive approach that helped the company adapt its model to address

barriers encountered in the context at successive turns. The Kenya case hews to this overall trajectory: the company has updated its business model to the point where it has become a key investor in several seemingly disparate, but ultimately connected, segments of the local economy. In many ways, therefore, the two country cases embody important aspects of the KeyMaker model described earlier, in which mini-grid developers go beyond their traditional remit of electricity provision to participate directly in agricultural value chains – typically in the downstream functions of storage and processing – as well as facilitate linkages to external markets for rural farmers (Mukoro et al., 2022; Peterschmidt & González Grandón, 2019; Pueyo et al., 2022).

The KeyMaker model does offer significant prospects for expanding rural participation in electricity and commodity markets. The model provides technical solutions for a set of practical problems encountered by rural farmers, including mini grid-powered cold storage that helps preserve perishable produce that would otherwise go to waste and managerial capabilities that can help reduce the precarity of farmer incomes (Peterschmidt & González Grandón, 2019). Indeed, Pueyo and DeMartino (2018) show how the growth of non-farm rural enterprises in Kenya is constrained by a lack of access to external markets, underscoring the importance of market linkages for rural economies. Nonetheless, our cases demonstrate a parallel reality, which is that production capacity is limited for the majority of smallholder farmers to begin with: the average farmer in sub-Saharan Africa cultivates less than five hectares of land per season, severely limiting their output (Kamara et al., 2019). When this is juxtaposed with the reality that agriculture employs the majority of rural dwellers in the region (over 70 percent in Nigeria and Kenya respectively) (FAO, 2024b, 2024a), the scale of the challenge becomes apparent.

The insight that the developers in our case studies contribute to knowledge and practice in this regard is what we have termed the *KeyStarter* model: rather than just intervening at the downstream stages of agricultural value chains, they also facilitate inputs *at or near the start*

of those value chains with a view to boosting the quantity and quality of the outputs at the end. In Nigeria, those inputs included access to finance and technology for increasing farm yields, while in Kenya, they included investments in feed and equipment to boost the quality – and hence the competitiveness – of poultry products.

It is worth noting that this level of investment in building the capacity of third-party ventures has been accompanied by significant levels of portfolio diversification by the respective companies (notably, C&I projects in the case of Nigeria and e-mobility in the case of Kenya). This means that early investments (and perhaps losses) in the rural businesses supported can be offset by the gains from more profitable lines of business within each company. This ability to cross-subsidise internal operations appears to be vital for maintaining the overall financial health of individual companies, and can perhaps be employed as a de-risking mechanism by local businesses which often have greater difficulty securing equity and debt for mini-grid development than their foreign counterparts (ESMAP, 2019).

The companies' approach to portfolio diversification, in turn, has been enabled by a high degree of flexibility and adaptability on their part, despite their being quite dissimilar in profile. Company A in Nigeria has modest local origins, even though it has grown steadily in recent years, while company B in Kenya is a multinational enterprise with origins in the global North and access to considerable amounts of foreign private capital. The long-term impacts of the KeyStarter approach applied in each case remain to be seen, but we argue that it has the potential to expand the rural mini-grid electricity consumer base beyond existing models. In particular, it presents an opportunity to achieve greater inclusiveness – especially of small-scale agricultural enterprises – in electricity use and broader economic gains, while at the same time increasing the profitability of mini-grid developers beyond what is typically obtained with the KeyMaker and other models.

Several limitations and tensions arise here. Critically, our analysis draws on two limited, albeit instructive case studies. Further research, including the action variety, will be required to assess the nature and size of the impacts of the KeyStarter model over time, as well as its scalability and replicability (see Dibaba et al., 2023). This opens up broader questions about the normative role of national and local governments in facilitating and propagating the model. The concern of the model with broadening inclusiveness at the rural agricultural base makes it a prime candidate for strong government (as well as donor) support. This point distinguishes the KeyStarter from the KeyMaker model, which is overwhelmingly concerned with boosting the value proposition of mini-grid development to prospective investors, by trying to minimise risks and maximise profits. This is an important goal, at least as far as enhancing the commercial viability of mini-grid businesses is concerned. Moreover, it may well be argued that the eventual outcome of the KeyMaker model in any case would be expanded rural electrification; however, as our case studies suggest, the multiplier effects – beyond electricity provision – on rural economies would be more muted. The KeyStarter model we highlight is more inherently focused on rural development, and it therefore aligns better with the interest of governments and donors in achieving a balance between impact and profitability (Peterschmidt & González Grandón, 2019).

Overall, while efforts to achieve commercial viability for mini grids are desirable, it is worth reflecting on the extent to which the conversation should be framed in strictly business terms when it affects some of the poorest communities in the world. This goes to the core of debates about enabling market participation for “bottom-of-the-pyramid” (BoP) populations as a way to catalyse development in poor regions (Bals et al., 2023; Knuckles, 2016). However, as Sesan et al. (2013) point out in their analysis of clean energy technology adoption in Nigeria, this is not always a straightforward proposition, as such models do not adequately capture important socioeconomic nuances that differentiate people at the so-called BoP. In sum, while the ongoing drive to make a business case for rural mini grids is aspirational, the evidence from our case studies suggests that more traditional development

inputs – public funding and subsidies, policy frameworks, technical assistance – need to be prioritised in the short to medium term to set host communities on the path to long-term prosperity.

Finally, we note that both the KeyMaker model and the KeyStarter model run the risk of ultimately becoming extractive and exploitative given that rural farmers may only benefit from the sale of primary commodities, which typically command lower returns than the value-added products that eventually reach the market through the developer (Carmignani & Avom, 2010; Drabo, 2017). Farmers are likely to get higher proceeds than usual under these novel arrangements, which would be an improvement on the status quo. Nonetheless, the discussion about the equitable distribution of overall benefits is an important one to foreground especially in the context of broader debates around the need to enable just energy transitions in African countries (R. H. Pedersen & Andersen, 2023; Sefa-Nyarko, 2024; Tladi et al., 2024).

6. Conclusion

This paper has interrogated narratives promoting the deployment of private sector-led mini-grids for rural electrification and development in sub-Saharan Africa. This development is in keeping with a broader trend which has seen several countries in the region shift from public to private ownership and management of electricity utilities in a bid to drive efficiency in the sector. While this market-driven model has spurred some interest in mini grids from private investors – with significant backing from donors, governments and development finance institutions – questions remain as to the extent to which it has facilitated inclusive access and growth, especially in rural poor contexts.

Of particular interest is the agriculture-energy nexus which has been recognised as a key intervention area in many mini-grid projects, given the importance of agriculture to many

rural SSA economies. We show from the literature how mini-grid business models have evolved over time, from an early focus on spurring productive uses of electricity to more sophisticated approaches such as the KeyMaker model which targets gaps in processing, marketing and transportation infrastructure that are apparent in the latter stages of many agricultural value chains. Notwithstanding the important innovations that have emerged from this evolution, the long-term commercial viability of mini grids remains in question, as does their ability to spur widespread demand among bottom-of-the-pyramid populations in rural areas – many of whom are small-scale farmers with low incomes and limited ability to pay for electricity.

Our paper makes a case for the possibility of simultaneously boosting mini-grid viability and broadening inclusiveness by making investments at earlier stages of agricultural value chains where opportunities exist to improve the quantity and quality of outputs and, by extension, the productivity and incomes of rural farmers. We term this the KeyStarter model, to denote a broadening of the KeyMaker concept established in the literature. Drawing on "thick descriptions" (Luhrmann, 2015) of two cases in Nigeria and Kenya respectively, we showed how mini-grid developers in both contexts iterated and tested interventions providing early-stage inputs with the aim of improving the bottom line for both their companies and the small-scale farmers involved in their schemes.

Under existing business models, benefits tend to be skewed toward small segments of rural populations, such as so-called anchor businesses, relatively well-established small and medium-scale enterprises and even mini-grid developers (Bukari et al., 2021; Pueyo et al., 2020), missing out on the opportunity to foster inclusive rural development through electrification. The KeyStarter model we describe presents an opportunity to reframe the agriculture-energy nexus to capture broader segments of rural populations that have historically been underrepresented in the distribution of energy access gains, in the process enabling greater inclusiveness on the demand side and profitability on the supply side.

These two seemingly disparate goals have largely been pursued independently of each other; this study represents one of very few attempts in the burgeoning mini-grid literature (q.v. Bandi et al., 2022) to bring them together.

The opportunity we highlight comes with challenges, notably, that of scalability due to the intensive nature of the financial and technical inputs required for substantive outputs. This is the point at which a mix of high-level coordination and ground-level support by public-sector actors, including governments and donors, needs to materialise. Apart from necessitating a rethinking of the scope of the agriculture-energy nexus, such an effort would also require a move from traditionally siloed ways of working to effective collaboration between various public departments – including, most directly, energy and agriculture, but also departments in related areas like transport, gender and social development.

Mini-grid business models continue to evolve: there is no definitive answer yet as to what models might yield optimal outcomes for all the stakeholders involved. The KeyStarter model we have presented here warrants further testing and development. Future research, including action-oriented research, should focus on quantifying the putative benefits to smallholder farmers and developers alike and identifying the social, economic and political supports required to maximise those benefits in different contexts.

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References

Adams, E. (2010). The joys and challenges of semi-structured interviewing. *Community Practitioner*, *83*(7), 18–22.

Adediran, O., Osabuohien, E., Silberberger, M., Osabohien, R., & Gbenro Adebayo, W. (2024). Agricultural value chain and households' livelihood in Africa: The case of Nigeria. *Heliyon*, *10*(7), e28655. https://doi.org/10.1016/j.heliyon.2024.e28655

AfDB. (2016). *Green Mini-Grids in Sub-Saharan Africa: Analysis of Barriers to Growth and the Potential Role of the African Development Bank in Supporting the Sector*. African Development Bank Green Mini-Grids Market Development Programme.

AfDB. (2017). *The New Deal on Energy for Africa: A transformative partnership to light up and power Africa by 2025*. African Development Bank Group.

AfDB. (2023). *Annual Development Effectiveness Review: Enhancing Africa's resilience*. African Development Bank Group.

Ahmed, S. K. (2024). The pillars of trustworthiness in qualitative research. *Journal of Medicine, Surgery, and Public Health*, *2*, 100051. https://doi.org/10.1016/j.glmedi.2024.100051

Aye, G. C., & Odhiambo, N. M. (2021). Oil prices and agricultural growth in South Africa: A threshold analysis. *Resources Policy*, *73*, 102196. https://doi.org/10.1016/j.resourpol.2021.102196

Azimoh, C. L., Klintenberg, P., Wallin, F., Karlsson, B., & Mbohwa, C. (2016). Electricity for development: Mini-grid solution for rural electrification in South Africa. *Energy*

Conversion and Management, *110*, 268–277. https://doi.org/10.1016/j.enconman.2015.12.015

Babayomi, O. O., Olubayo, B., Denwigwe, I. H., Somefun, T. E., Adedoja, O. S., Somefun, C. T., Olukayode, K., & Attah, A. (2023). A review of renewable off-grid mini-grids in Sub-Saharan Africa. *Frontiers in Energy Research*, *10*. https://doi.org/10.3389/fenrg.2022.1089025

Baker, L., & Burton, J. (2024). From the minerals-energy complex to a just transition? In S. Mohamed & A. Ngoma (Eds.), *The Evolving Structure of South Africa's Economy: Faultlines and Futures* (pp. 270–296). African Books Collective.

Baker, L., Sesan, T., Bhattacharyya, S., Bukari, D., Meena, S., Onsongo, E., Oyinlola, M., Sawe, E., Otu-Eleri, E., Uduka, U., Handem, Y., Onjala, B., & Katyega, M. (2022). *Of monopolies and mini grids: Case studies from Kenya, Tanzania, Nigeria and Senegal* (Sustainability, Inclusiveness and Governance of Mini-Grids in Africa (SIGMA) Working Paper Series).

Bals, L., Huang, F., Tate, W. L., & Rosca, E. (2023). Creating social value at the bottom of the pyramid: Elaborating resource orchestration via social intermediaries. *Journal of Business Research*, *168*, 114209. https://doi.org/10.1016/j.jbusres.2023.114209

Bandi, V., Sahrakorpi, T., Paatero, J., & Lahdelma, R. (2022). The paradox of mini-grid business models: A conflict between business viability and customer affordability in rural India. *Energy Research & Social Science*, *89*, 102535. https://doi.org/10.1016/j.erss.2022.102535

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2018). Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. *Renewable and Sustainable Energy Reviews*, *90*, 1060–1068. https://doi.org/10.1016/j.rser.2017.11.003

Bhattacharyya, S. C. (2014). Viability of off-grid electricity supply using rice husk: A case study from South Asia. *Biomass and Bioenergy*, *68*, 44–54. https://doi.org/10.1016/j.biombioe.2014.06.002

Bhattacharyya, S. C., & Palit, D. (2016). Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? *Energy Policy*, *94*, 166–178. https://doi.org/10.1016/j.enpol.2016.04.010

Blimpo, M. P., & Postepska, A. (2017). *Why is Household Electricity Uptake Low in Sub-Saharan Africa?* World Bank.

Brent, A. C., & Rogers, D. E. (2010). Renewable rural electrification: Sustainability assessment of mini-hybrid off-grid technological systems in the African context. *Renewable Energy*, *35*(1), 257–265. https://doi.org/10.1016/j.renene.2009.03.028

Bukari, D., Kemausuor, F., Quansah, D. A., & Adaramola, M. S. (2021). Towards accelerating the deployment of decentralised renewable energy mini-grids in Ghana: Review and analysis of barriers. *Renewable and Sustainable Energy Reviews*, *135*, 110408. https://doi.org/10.1016/j.rser.2020.110408

Cabanero, A., Nolting, L., & Praktiknjo, A. (2020). Mini-Grids for the Sustainable Electrification of Rural Areas in Sub-Saharan Africa: Assessing the Potential of KeyMaker Models. *Energies*, *13*(23), Article 23. https://doi.org/10.3390/en13236350

Carbon Africa Limited, Trama TecnoAmbiental S.L., esearch Solutions Africa Limited, & Energy Research Centre of the Netherlands. (2016). *Kenya Market Assessment for Off-Grid Electrification*.

Carmignani, F., & Avom, D. (2010). The social development effects of primary commodity export dependence. *Ecological Economics*, *70*(2), 317–330. https://doi.org/10.1016/j.ecolecon.2010.09.003

Carroll, T., & Jarvis, D. S. L. (2015). The New Politics of Development: Citizens, Civil Society, and the Evolution of Neoliberal Development Policy. *Globalizations*, *12*(3), 281–304. https://doi.org/10.1080/14747731.2015.1016301

Central Bank of Nigeria. (n.d.). *Deposit and lending rates in the banking industry*. https://www.cbn.gov.ng/Documents/depositandlending.asp

Chamarande, T., Etienne, E., & Mathy, S. (2024). Sizing isolated mini-grids in Kenya: Risk transfer to deal with multidimensional uncertainties and constraints. *Renewable and Sustainable Energy Transition*, *5*, 100078. https://doi.org/10.1016/j.rset.2024.100078

Chandra, Y., & Shang, L. (2019). Inductive Coding. In Y. Chandra & L. Shang (Eds.), *Qualitative Research Using R: A Systematic Approach* (pp. 91–106). Springer Nature. https://doi.org/10.1007/978-981-13-3170-1_8

Cyril, A. O., Ujah, C. O., Ekwueme, B. N., & Asadu, C. O. (2024). Photovoltaic mini-grid incorporation: The panacea for electricity crisis in sub-Saharan Africa. *Unconventional Resources*, *4*, 100079. https://doi.org/10.1016/j.uncres.2024.100079

Davis, B., Di Giuseppe, S., & Zezza, A. (2017). Are African households (not) leaving agriculture? Patterns of households' income sources in rural Sub-Saharan Africa. *Food Policy*, *67*, 153–174. https://doi.org/10.1016/j.foodpol.2016.09.018

DeJonckheere, M., & Vaughn, L. M. (2019). Semistructured interviewing in primary care research: A balance of relationship and rigour. *Family Medicine and Community Health*, *7*(2), e000057. https://doi.org/10.1136/fmch-2018-000057

Dibaba, H., Tomas Fillol, L., Pinomaa, A., & Honkapuro, S. (2023). Measuring success: Evaluating the business model of rural mini-grid ecosystems. *Energy Research & Social Science*, *106*, 103296. https://doi.org/10.1016/j.erss.2023.103296

Drabo, A. (2017). Climate change mitigation and agricultural development models: Primary commodity exports or local consumption production? *Ecological Economics*, *137*, 110–125. https://doi.org/10.1016/j.ecolecon.2017.03.014

Eder, J. M., Mutsaerts, C. F., & Sriwannawit, P. (2015). Mini-grids and renewable energy in rural Africa: How diffusion theory explains adoption of electricity in Uganda. *Energy Research & Social Science*, *5*, 45–54. https://doi.org/10.1016/j.erss.2014.12.014

Edsand, H.-E., & Bångens, L. (2024). Power struggles: Advances and roadblocks of solar powered mini grids in Tanzania. *Energy Reports*, *11*, 342–354. https://doi.org/10.1016/j.egyr.2023.12.010

ESMAP. (2017). *Mini Grids in Kenya: A case study of a market at a turning point*. World Bank Energy Sctor Management Assistance Program.

ESMAP. (2019). *Mini grids for half a billion people: Market outlook and handbook for decision makers (2019)* (Technical Report 014/19). Energy Sector Management Assistance Program.

ESMAP. (2022). *Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers*. World Bank Energy Sctor Management Assistance Program.

Fajardo, A., Baker, L., Bhattacharyya, S., Sesan, T., Katyega, M., Kerr, D., & Barnett, A. (2023). *Understanding business models and access to finance for mini grid development in sub-Saharan Africa* (3; Sustainability, Inclusiveness and Governance of Mini-Grids in Africa (SIGMA) Working Paper Series).

Falchetta, G., Adeleke, A., Awais, M., Byers, E., Copinschi, P., Duby, S., Hughes, A., Ireland, G., Riahi, K., Rukera-Tabaro, S., Semeria, F., Shendrikova, D., Stevanato, N., Troost, A., Tuninetti, M., Vinca, A., Zulu, A., & Hafner, M. (2022). A renewable energy-centred research agenda for planning and financing Nexus development objectives in rural sub-Saharan Africa. *Energy Strategy Reviews*, *43*, 100922. https://doi.org/10.1016/j.esr.2022.100922

FAO. (2022). *Rural Livelihoods Information System (RuLIS) Country Brief: Nigeria General Household Survey 2018-2019*. Food and Agricultural Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/1775a0a9-8796-4fee-bcc2-759ff92759fc/content

FAO. (2024a). *Kenya at a glance | FAO in Kenya*. Food and Agriculture Organization of the United Nations. https://www.fao.org/kenya/fao-in-kenya/kenya-at-a-glance/en/

FAO. (2024b). *Nigeria at a glance | FAO in Nigeria*. Food and Agriculture Organization of the United Nations. https://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development.

International Journal of Qualitative Methods, *5*(1), 80–92. https://doi.org/10.1177/160940690600500107

GEAPP. (no date). *Nigeria: Energizing agriculture through productive uses of energy*. Global Energy Alliance for People and Planet. https://www.energyalliance.org/energizing-agriculture-through-productive-uses-of-energy/

Gill-Wiehl, A., Miles, S., Wu, J., & Kammen, D. M. (2022). Beyond customer acquisition: A comprehensive review of community participation in mini grid projects. *Renewable and Sustainable Energy Reviews*, *153*, 111778. https://doi.org/10.1016/j.rser.2021.111778

Herbert, C., & Phimister, E. (2019). Private sector-owned mini-grids and rural electrification: A case study of wind-power in Kenya's tea industry. *Energy Policy*, *132*, 1288–1297. https://doi.org/10.1016/j.enpol.2019.06.031

Hoeck, I., Steurer, E., Dolunay, Ö., & Ileka, H. (2022). Challenges for off-grid electrification in rural areas. Assessment of the situation in Namibia using the examples of Gam and Tsumkwe. *Energy, Ecology and Environment*, *7*(5), 508–522. https://doi.org/10.1007/s40974-021-00214-5

Huber, M., Namockel, N., Rezgui, R., Küppers, M., & Heger, H. J. (2021). Electrification seeds – A flexible approach for decentralized electricity supply in developing countries. *Energy for Sustainable Development*, *62*, 176–185. https://doi.org/10.1016/j.esd.2021.04.001

IEA. (2023). *Africa Energy Outlook 2022*. International Energy Agency. https://iea.blob.core.windows.net/assets/220b2862-33a6-47bd-81e9-00e586f4d384/AfricaEnergyOutlook2022.pdf

Ikuemonisan, E. S., & Ajibefun, I. A. (2021). Economic Implications of Smallholders' Collaborative Groupings on Household Income and Adaptability to Climate Change in Nigeria. *Sustainability*, *13*(24), Article 24. https://doi.org/10.3390/su132413668

Johnson, D. G., & Schuh, G. E. (2019). *The Role Of Markets In The World Food Economy*. CRC Press. https://doi.org/10.1201/9780429314391

Kallio, H., Pietilä, A.-M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, *72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Kamara, A., Abdul, C., Rhodes, E. R., & Cooke, R. A. (2019). The Relevance of Smallholder Farming to African Agricultural Growth and Development. *African Journal of Food, Agriculture, Nutrition and Development*, *19*(1). https://doi.org/18697/ajfand.84.BLFB1010

Kapole, F., Mudenda, S., & Jain, P. (2023). Study of major solar energy mini-grid initiatives in Zambia. *Results in Engineering*, *18*, 101095. https://doi.org/10.1016/j.rineng.2023.101095

Knuckles, J. (2016). Business models for mini-grid electricity in base of the pyramid markets. *Energy for Sustainable Development*, *31*, 67–82. https://doi.org/10.1016/j.esd.2015.12.002

Kumar, P. (2015). *Nepal—Scaling Up Electricity Access through Mini and Micro Hydropower Applications: A strategic stock-taking and developing a future roadmap*. World Bank.

Luhrmann, T. M. (2015). Thick Description: Methodology. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)* (pp. 291–293). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.44057-2

Lukuyu, J., Fetter, R., Krishnapriya, P. P., Williams, N., & Taneja, J. (2021). Building the supply of demand: Experiments in mini-grid demand stimulation. *Development Engineering*, *6*, 100058. https://doi.org/10.1016/j.deveng.2020.100058

Malhotra, A., Schmidt, T. S., Haelg, L., & Waissbein, O. (2017). Scaling up finance for off-grid renewable energy: The role of aggregation and spatial diversification in derisking investments in mini-grids for rural electrification in India. *Energy Policy*, *108*, 657–672. https://doi.org/10.1016/j.enpol.2017.06.037

Mambwe, C., Schröder, K.-W., Kügel, L., & Jain, P. (2022). Benchmarking and comparing effectiveness of mini-grid encroachment regulations of 24 African countries ✦ A

guide for governments and energy regulators to develop effective grid encroachment regulations. *Solar Compass*, *1*, 100008. https://doi.org/10.1016/j.solcom.2022.100008

Monyei, C. G., Akpeji, K. O., Oladeji, O., Babatunde, O. M., Aholu, O. C., Adegoke, D., & Imafidon, J. O. (2022). Regional cooperation for mitigating energy poverty in Sub-Saharan Africa: A context-based approach through the tripartite lenses of access, sufficiency, and mobility. *Renewable and Sustainable Energy Reviews*, *159*, 112209. https://doi.org/10.1016/j.rser.2022.112209

Mukoro, V., Sharmina, M., & Gallego-Schmid, A. (2022). A review of business models for access to affordable and clean energy in Africa: Do they deliver social, economic, and environmental value? *Energy Research & Social Science*, *88*, 102530. https://doi.org/10.1016/j.erss.2022.102530

Nadji.Bi Sénégal. (no date). *Easy solar for everyone*. Nadji.Bi Group SA. https://www.nadjibi.com/en_US/

Ngowi, J. M., Bångens, L., & Ahlgren, E. O. (2019). Benefits and challenges to productive use of off-grid rural electrification: The case of mini-hydropower in Bulongwa-Tanzania. *Energy for Sustainable Development*, *53*, 97–103. https://doi.org/10.1016/j.esd.2019.10.001

Nuru, J. T., Rhoades, J. L., & Gruber, J. S. (2021). Evidence of adaptation, mitigation, and development co-benefits of solar mini-grids in rural Ghana. *Energy and Climate Change*, *2*, 100024. https://doi.org/10.1016/j.egycc.2021.100024

Ogeya, M., Muhoza, C., & Johnson, O. W. (2021). Integrating user experiences into mini-grid business model design in rural Tanzania. *Energy for Sustainable Development*, *62*, 101–112. https://doi.org/10.1016/j.esd.2021.03.011

Osae-Brown, A. (2022). Price Pressures Build in Nigeria as Diesel Costs Surge 200%. *Bloomberg Markets*. https://www.bloomberg.com/news/articles/2022-07-20/price-pressures-build-in-nigeria-as-diesel-costs-surge-200#xj4y7vzkg

Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying Business Models: Origins, Present, and Future of the Concept. *Communications of the Association for Information Systems*, *16*(1). https://doi.org/10.17705/1CAIS.01601

Pedersen, M. B., & Nygaard, I. (2018). System building in the Kenyan electrification regime: The case of private solar mini-grid development. *Energy Research & Social Science*, *42*, 211–223. https://doi.org/10.1016/j.erss.2018.03.010

Pedersen, R. H., & Andersen, O. W. (2023). A contested agenda: Energy transitions in lower-income African countries. *Energy Policy*, *175*, 113496. https://doi.org/10.1016/j.enpol.2023.113496

Peterschmidt, N., & González Grandón, T. (2019). *KeyMaker Model Fundamentals: Mini-grids as a tool for inclusion of deep rural communities*. SE4All Africa and African Development Bank.

Power for All. (2019). *Power for All Fact Sheet: Appliance financing stimulates mini-grid demand and boosts revenue*. https://www.powerforall.org/application/files/3415/6931/4680/Appliance_financing_stimulates_mini-grid_demand_and_boosts_revenue2.pdf

Pueyo, A., Carreras, M., & Ngoo, G. (2020). Exploring the linkages between energy, gender, and enterprise: Evidence from Tanzania. *World Development*, *128*, 104840. https://doi.org/10.1016/j.worlddev.2019.104840

Pueyo, A., & DeMartino, S. (2018). The impact of solar mini-grids on Kenya's rural enterprises. *Energy for Sustainable Development*, *45*, 28–37. https://doi.org/10.1016/j.esd.2018.04.002

Pueyo, A., Ngoo, G., Daulinge, E., & Fajardo, A. (2022). *The Quest for Scalable Business Models for Mini-Grids in Africa: Implementing the Keymaker Model in Tanzania* (89; IDS Research Report). Institute of Development Studies. 10.19088/IDS.2022.071

REA. (n.d.). *REA's Strategic Interventions: Adopting a programmatic approach to deliver capital projects*. Rural Electrification Agency.

REA. (2024). Results Based Financing for Productive Appliances & Equipment – Nigeria Electrification Project. *Rural Electrification Agency*. https://nep.rea.gov.ng/result-based-financing-for-productive-appliances-equipment/

Ritter, C., Koralesky, K. E., Saraceni, J., Roche, S., Vaarst, M., & Kelton, D. (2023). *Invited review:* Qualitative research in dairy science—A narrative review. *Journal of Dairy Science*, *106*(9), 5880–5895. https://doi.org/10.3168/jds.2022-23125

Safdar, T. (2017). *Business models for mini grids*. Smart Villages Initiative.

Schmitter, P., Kibret, K. S., Lefore, N., & Barron, J. (2018). Suitability mapping framework for solar photovoltaic pumps for smallholder farmers in sub-Saharan Africa. *Applied Geography*, *94*, 41–57. https://doi.org/10.1016/j.apgeog.2018.02.008

Sefa-Nyarko, C. (2024). Ghana's National Energy Transition Framework: Domestic aspirations and mistrust in international relations complicate 'justice and equity'. *Energy Research & Social Science*, *110*, 103465. https://doi.org/10.1016/j.erss.2024.103465

Sesan, T., Raman, S., Clifford, M., & Forbes, I. (2013). Corporate-Led Sustainable Development and Energy Poverty Alleviation at the Bottom of the Pyramid: The Case of the CleanCook in Nigeria. *World Development*, *45*, 137–146. https://doi.org/10.1016/j.worlddev.2012.10.009

Sesan, T., Uduka, U., Baker, L., Ugwu, O., Eleri, E., & Bhattacharyya, S. (2024). Exploring the connections between mini-grid market regulation and energy access expansion: The case of Nigeria. *Energy Policy*, *184*, 113891. https://doi.org/10.1016/j.enpol.2023.113891

Soares, C. A., Shendrikova, D., Crevani, G., Silinto, B., & Colombo, E. (2023). Enabling factors for the development of mini-grid solutions in Mozambique: A PESTLE-based analysis. *Energy Strategy Reviews*, *45*, 101040. https://doi.org/10.1016/j.esr.2022.101040

Soni, R., & Kawahara, T. (2020). Three key challenges to scale up the mini-grid sector. *UN Sustainable Energy for All News*. https://www.seforall.org/news/three-key-challenges-to-scale-up-the-mini-grid-sector

Taylor, G. A. J., & Blake, B. J. (2015). Key informant interviews and focus groups. In M. de Chesnay (Ed.), *Nursing research using data analysis: Qualitative designs and methods in nursing* (pp. 153–166). Springer.

Tladi, B., Kambule, N., & Modley, L.-A. (2024). Assessing the social and environmental impacts of the just energy transition in Komati, Mpumalanga Province, South Africa. *Energy Research & Social Science*, *111*, 103489. https://doi.org/10.1016/j.erss.2024.103489

UNDESA. (2023). *Policy briefs in support of the UN high-level political forum 2023: Advancing SDG7 in Africa*. United Nations Department of Economic and Social Affairs. https://sdgs.un.org/sites/default/files/2023-06/2023%20Advancing%20SDG7%20in%20the%20Africa-062923.pdf

USADF. (n.d.). *Off-Grid Renewable Energy*. United States African Development Foundation. https://www.usadf.gov/sectors/3

USAID. (2022). *Power Africa Nigeria Power Sector Program: Productive use cold storage systems in Nigeria*. United States Agency for International Development (USAID) and National Renewable Energy Laboratory (NREL). https://pdf.usaid.gov/pdf_docs/PA00Z8X7.pdf

Uyanga, V. A., Bello, S. F., Bosco, N. J., Jimoh, S. O., Mbadianya, I. J., Kanu, U. C., Okoye, C. O., Afriyie, E., Mak-Mensah, E., Agyenim-Boateng, K. G., Ogunyemi, S. O., Nkoh, J. N., Olasupo, I. O., Karikari, B., & Ahiakpa, J. K. (2024). Status of agriculture and food security in post-COVID-19 Africa: Impacts and lessons learned. *Food and Humanity*, *2*, 100206. https://doi.org/10.1016/j.foohum.2023.100206

van Hove, E., Johnson, N. G., & Blechinger, P. (2022). Evaluating the impact of productive uses of electricity on mini-grid bankability. *Energy for Sustainable Development*, *71*, 238–250. https://doi.org/10.1016/j.esd.2022.10.001

Vanadzina, E., Pinomaa, A., Honkapuro, S., & Mendes, G. (2019). An innovative business model for rural sub-Saharan Africa electrification. *Energy Procedia*, *159*, 364–369. https://doi.org/10.1016/j.egypro.2019.01.001

Wagemann, B., & Manetsgruber, D. (2016). Risk Management for Mini-grid Deployment in Rural Areas. *Energy Procedia*, *103*, 106–110. https://doi.org/10.1016/j.egypro.2016.11.257

Wassie, Y. T., & Ahlgren, E. O. (2024). Understanding the load profiles and electricity consumption patterns of PV mini-grid customers in rural off-grid east africa: A data- driven study. *Energy Policy*, *185*, 113969. https://doi.org/10.1016/j.enpol.2023.113969

World Bank. (2021). *The Energy Progress Report*. Tracking SDG 7. https://trackingsdg7.esmap.org/

World Bank. (2023a). *Nigeria to Expand Access to Clean Energy for 17.5 Million People* [Text/HTML]. World Bank. https://www.worldbank.org/en/news/press-release/2023/12/15/nigeria-to-expand-access-to-clean-energy-for-17-5-million-people

World Bank. (2023b). *Solar mini grids could sustainably power 380 million people in Africa by 2030 – if action is taken now* (Press Release 055). World Bank.

Yeboah, F. K., & Jayne, T. S. (2018). Africa's Evolving Employment Trends. *The Journal of Development Studies*, *54*(5), 803–832. https://doi.org/10.1080/00220388.2018.1430767

Zajicek, C. (2023). *How solar mini-grids can bring cheap, green electricity to rural Africa*.

Overseas Development Institute. https://odi.org/en/insights/how-solar-mini-grids-can- bring-cheap-green-electricity-to-rural-africa/